BULLETIN

OF THE

DEPARTMENT OF MINING AND METALLURGY,

UNIVERSITY OF CALIFORNIA.

Present Problems in the Training of Mining Engineers.

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A PAPER READ BEFORE THE CONGRESS OF ARTS AND SCIENCES, ST. LOUIS, AND ALSO BEFORE THE AMERICAN INSTITUTE OF MINING ENGINEERS, SEPTEMBER, 1904.

1905.

[TRANSACTIONS OF THE AMERICAN INSTITUTE OF MINING ENGINEERS.]

Present Problems in the Training of Mining Engineers.*

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"THE man is always greater than his work." The training of the men who are to develop the mineral resources of the world is the most important problem connected with mining engineering. It becomes ever more important to civilization as the mineral wealth of the earth approaches exhaustion. I have therefore decided to consider a few of the more important problems arising in the training of the mining engineer, and especially those arising in America.

THE PECULIAR NATURE OF MINERAL WEALTH.

Mining and Agriculture are the two fundamental arts. Without the latter our existence would be precarious; without the former, our civilization impossible. Agriculture furnishes that regular supply of food and raiment which leads to the growth of large communities in which cultivated leisure first becomes possible; while mining furnishes the metallic thread from which is woven that complex fabric we call civilization.

But in these two arts the conditions for success are widely different. Most of the crops that the farmer reaps may be harvested year after year, and the proper fertilizers being added, he may continue the annual harvest indefinitely, while, as a result of cultivation, his farm becomes yearly more valuable.

But the crop the miner reaps can be harvested but once in the history of the race. Our mineral wealth has taken unknown ages to mature in the bosom of the earth. The ripened fruit can be plucked but once. There are no fertilizers for worked out mines. It never pays to work over a mine that has been

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* Presented at the Congress of Arts and Sciences at the Louisiana Purchase Exposition, St. Louis, September, 1904, and at the Meeting of the American Institute of Mining Engineers held at the same place and date.

"robbed," either through ignorance or lack of skill; and a worked out mine is utterly worthless.

These differences between the two kinds of natural wealth have been long recognized, and have led in the old world to a very conservative policy in the utilization of mineral wealth.

Though the fragmentary history of primitive mining-law is full of contradictions, it would seem that the development of the mineral wealth of the world was at first everywhere due to the free initiative of the miner, whose exertions were stimulated by the right to possess what his energies discovered. But everywhere in the old world the mailed hand of the sovereign soon seized this important source of wealth and power. It was used at first exclusively for his own benefit, but as more enlightened views of the duty of the sovereign to his people spread through Europe at the end of the middle ages, these special rights and privileges have been used more and more for the benefit of the whole people. At the present time in some of the continental countries individual initiative and ownership has asserted itself once more; still, it is generally true that in most of the countries of continental Europe the mines are either owned or are worked under the direction of the government. In these matters the policy of Great Britain and her colonies has been, in general, intermediate between that of the United States and of continental Europe. Hence, in what follows I shall dwell chiefly on the differences between Continental and American customs.

Continental and American Mining-Schools.

When European mining-schools were first organized they also came naturally under government control, and there consequently resulted a close union between the mines and the mining-schools. This in turn led to many other important consequences. A regular career was opened for the graduates of the mining-schools either by their direct employment in mines operated by the government or in the inspection and direction of the working of mines under government control. As a consequence of this policy, well-trained men have always had the management of the mines under a sort of civil service system. And also a wise conservation of the mineral wealth of these countries has resulted; the mines are worked syste-

matically and have often kept producing a steady output for several hundred years, while in our country they would have been worked out and abandoned in one or two decades. While, according to our ideas, there are drawbacks to the Continental policy, it certainly lends a restraining influence to the natural uncertainties of mining life; it gives a more certain tenure of office to the mining officials; and, consequently, results in a more conservative policy in the management. It effects a more complete extraction of all the ore in the deposit, a better avoidance of wastes and a more complete utilization of all the side products. On the whole, the system, when wisely administered, leads to excellent results.

Its effects on the early development of the mining-schools were also favorable. The close relation between the mines and the mining-schools made it easy for the one to assist the other- The graduates of the mining-schools were as sure of employment in an honorable profession as are the graduates from our government military and naval academies at West Point and Annapolis. Historically, this connection has lent the air of distinction that clings to the profession of the mining engineer apart from his function as a mere money-getter.

On the Continent two grades of mining-schools have grown up. The *Bergschule* and the *Bergakademie*. The *Bergschule* trains working miners for the duties of mine foremen, while the *Bergakademie* trains young men of the educated class for the duties of the mining engineer.

The system here outlined possesses many advantages and is admirably adapted to the countries where it originated. But it would be impossible in America. In the first place our government gives away its mines and does not attempt to control either them or the mining-schools. No official connection either exists or is possible between them. Moreover, though there is much to be said in its favor, the sharp distinction drawn between the *Bergschule* and the *Bergakademie* in Europe is at variance with American ideals of democracy.

It has become an axiom with us that not only genius, but also talent, ability and capacity of any kind, are too precious to the entire community to allow them to go to waste. We err, indeed, by going to the other extreme. But there is no doubt that the wonderful industrial progress of America is

largely due to that equality of opportunity that is here practically open to every young man of ability.

The American Temperament.

It has often been claimed that the American temperament is due to our peculiar climatic conditions. As a matter of fact nearly all the climates of the globe characterize our country. And in order to disprove this theory one has only to cross the narrow line that bounds our country either to the north or to the south to find a relief from the strenuosity of the American temperament. The American temperament is due, not to climatic conditions, but to a mental attitude toward life. When a man feels that his future depends not so much upon his own efforts, but mainly upon the position to which he was born, he is, if not contented with his lot, at least more likely to be reconciled to it; for he feels it idle to waste himself in useless effort. But, if you can convince such a man that there is no limit to his ambition but that of his own powers, you have fired him with the most powerful stimulant that can influence human nature. It is this stimulant, working day and night for over a century upon men descended from every race in Europe, that has produced the American temperament.

It is a temperament that was not unknown in Greece in its great democratic days. Republican Rome felt it, too. But in monarchies its influence is mostly confined to the army and the navy. For in war times the best man must be had regardless of his birth. Napoleon overran Europe by declaring to his men: "Every soldier carries the Marshall's baton in his knapsack."

The Rôle of "The Practical Miner" in America.

Nowhere in America has this influence been more keenly felt than in the mining industry, particularly in the Western States. The policy of our government in throwing open to the hardy prospector its ownership in the mineral wealth of these States has stimulated men without previous technical education and training to accomplish what in older countries would be regarded as physical impossibilities.

It is true that the path has been marked with waste of money, labor and life. Blunders, failures there have been, and still

are, innumerable. But the accomplishment is all the more remarkable when we recognize these facts, for it testifies to the almost superhuman energy with which these obstacles have been overcome.

We are greatly indebted to the old world for its contributions to the mining and metallurgic art, but we are beginning to repay the loan with generous interest. And, to tell the truth, it is largely due to the plain average American, without college education or training, that many of these advances have been made. Every one who has mixed much with American miners has met and honored many such uncrowned kings. *And unless the graduate of American mining-schools is ready and willing to meet with this kind of competition without fear or favor, he will surely and deservedly fail.*

This was the first great problem that confronted the American mining-schools and it has proved their greatest advantage. There is no royal road for their graduates. They cannot depend on the government for places in the mines, because the government neither owns, works, nor attempts to control the mines. Neither can they look to their diplomas as a guarantee of employment.

The American attitude on this question has hitherto been very different from the European. Credentials, degrees, diplomas and recommendations that in Europe carry great weight, in America often receive but scant attention. The American often amuses himself with titles, but deep down in his nature is an instinctive distrust of anyone who takes them seriously. Among the men who have done most to develop the mineral wealth of our country this feeling is particularly strong. What a man is, is more important to them than, Who he is. What a man knows interests them but little; it concerns them much more, what use he can make of this knowledge.

Herbert Spencer, a radical in so many of his opinions, was quite in sympathy with this point of view. I quote from his *Autobiography*, vol. i., p. 199, beginning with a passage from a letter to Herbert Spencer from his father.

"'I am glad you find your inventive powers are beginning to develop themselves. Indulge a grateful feeling for it. Recollect, also, the never-ceasing pains taken with you on that point in early life.'" Herbert Spencer then adds:

"The last sentence is quoted not only in justice to my father, but also as conveying a lesson to educators. Though the results which drew forth his remark were in the main due to that activity of the constructive imagination which I inherited from him, yet his discipline during my boyhood and youth doubtless served to increase it. Culture of the humdrum sort, given by those who ordinarily pass for teachers would have left the faculty undeveloped."

Footnote by Mr. Spencer. "Let me name a significant fact, published while the proof of this paper is under correction. In *The Speaker* for April 9, 1892, Mr. Poulteney Bigelow gives an account of an interview with Mr. Edison, the celebrated American inventor. Here are some quotations from it: To my question as to where he found the best young men to train as his assistants, he answered emphatically: 'The college-bred ones are not worth a —— ! I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work.' Mr. Edison did not conceal his contempt for the college training of the present day in so far as it failed to make boys practical and fit to earn their living. With this opinion may be joined two startling facts; the one that Mr. Edison, probably the most remarkable inventor who ever lived, is himself a self-trained man; and the other that Sir Benjamin Baker, the designer and constructor of the Forth Bridge, the grandest and most original bridge in the world, received no regular engineering education."

Mr. Spencer might have added himself to this list of remarkable self-made men, for his schooling, though excellent as far as it went, was very meager, and he made himself what he came to be.

In the words: "*I don't know why, but they don't seem able to begin at the beginning and give their whole heart to the work*," Mr. Edison has put his finger with singular acuteness on the principal failing of improperly trained college students. The reason why they are not willing "to begin at the beginning and give their whole heart to the work" is because their education has often been so exclusively theoretical that they are filled with the conceit of learning, and they have an inordinate idea of their untried abilities. Hence their unwillingness "to begin at the beginning." They feel that they ought to begin at the end and be put in charge of everything. If, in their training, theory and practice had gone hand in hand, this conceit, which is natural to all young men, would have been soon dissipated by the hard realities of practice, and the young men would have been more willing "to begin at the beginning," and more ready and able "to give their whole heart to the work."

At the same time I cannot help thinking that Mr. Edison must have been unfortunate in his choice of "college-bred assistants," or in the colleges that trained them; for in opposition to his experience may be quoted the practice of a large number of his important rivals in the electrical business and of an increasing number of iron and steel, railway, bridge construction and mining and smelting companies, to draw upon the graduates of engineering schools for their assistants; and, where they wisely insist on the men beginning at the bottom and working their way up according to merit, the results have been, on the whole, more and more satisfactory as the engineering schools have adjusted themselves more closely to their environment. I have given these strong statements of the failings of college-bred men, not to endorse them, but because they contain an important truth that must be recognized and met.

This condition of public opinion has from the very first forced the American mining-schools to stand on their own merits. Whatever success they have achieved has been due to this hard necessity.[1] The atmosphere surrounding European mining-schools is so different from that in America that graduates from such schools have always found in America much

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[1] I append in this connection the following concise and caustic note from the *Engineering and Mining Journal*, p. 403, June 12, 1880, which shows the condition of affairs in America only 25 years ago. The hope expressed in the last paragraph has since been largely realized to the benefit of all concerned.

"A correspondent writes us, asking 'If it is absolutely necessary to be a graduate of a school of mines before being able to engage in the business of a mining engineer.' Certainly not; in fact, before engaging in the business of mining engineering it does not appear to be absolutely necessary that a man should know anything at all, as our correspondent can very well satisfy himself by visiting nine out of ten of the mines nearest to him, wherever he may be. Had our correspondent asked, whether it would be desirable that a man should be a graduate of a school of mines before engaging in mining engineering, we should have answered in the affirmative, for the simple reason that the course of study in a school of mines is calculated to give the elementary education necessary for a mining engineer, and, other things being equal, should give its recipient an advantage over those who have learned the business only in practice. The course of study in a school of mines is not, however, sufficient to qualify a mining engineer to take charge of important works; but it forms an excellent foundation upon which to build a practical knowledge of the business.

"Many of our mines are now under the direction of competent engineers and the results of this policy are justifying the hope that, before very long, all companies of good standing will place their mines in charge of men specially trained for the discharge of the responsible and important duties of a mining engineer."

to be unlearned. The American mining-schools have already adapted themselves so well to their environment that this year, for the first time in nearly a century, there were no American mining students in the great Saxon Mining-School at Freiberg. And already some of the American mining-schools have exceeded in wealth, in equipment and in attendance this most famous of all mining-schools.

Is Theoretical Training Worth While?

But, it may be urged, if practical men without theoretical training have accomplished so much, what is the use of theoretical training? Why not confine the education of the mining engineer to the purely practical part, omitting all the theory? The answer is not far to reach. The purely practical man has indeed accomplished wonders, but at the cost of enormous waste of money, labor and human lives. For every success that he has made there are a thousand failures which only the thoughtful notice. There is no profession where practical experience is more essential than in mining, but the necessity of a sound scientific training is even more indispensable. A hard-headed Arizona miner once put the matter very tersely when the superiority of the "practical man" was being strongly urged, by saying: "I have had thirty years' practical experience in mining, and I would give twenty-five of those years to have had a good technical education to begin with." He was clearly right, for a man well trained in fundamentals has a broader grasp and can more intelligently and rapidly utilize his experience than a man without this training.

Either theory or practice alone is helpless; united they are invincible. And the brilliant success of the American mining engineer in so many fields has been because these two important elements have been so thoroughly blended in his training.

Specialization, How Much and When?

This problem arises from the great breadth of training which has been necessary to the American mining engineer. Like the soldier or sailor, he must go to the ends of the earth. His work often lies beyond the borders of civilization, where, like Prospero upon his lonely isle, he must conjure up his resources from the vasty deep; and he must act in turn as geol-

ogist and as civil, mechanical, hydraulic, electrical, mining or metallurgical engineer. The problem is: What degree of specialization shall be undertaken in an undergraduate mining course? Shall we endeavor to turn out at graduation specialists, each completely equipped for work in some narrow line, or shall we rather attempt to establish a broad basal training in the physical sciences on which the future engineer may safely build, as circumstances may require?

The former system is the European practice, such parallel courses as mining engineering (further subdivided into coal- and metal-mining), metallurgical engineering (also subdivided into two branches), mine-surveying, mine-geology, and the like, being commonly-recognized departments within which the student specializes in an undergraduate course.

In an old community, where the mines are under government control, and customs have crystallized, such a specialization is wise. Each student can estimate with certainty the need for the specialty he chooses, and be sure of employment in his own line.

But under American conditions (with a few notable exceptions, where conditions have become relatively stable), it is unsafe to specialize too soon and on too narrow a basis. Here the mere specialist, outside of his specialty, is as helpless as a hermit crab outside of his shell, and unless he possesses the ability to adapt himself speedily to a rapidly changing environment, is sure to go under. The present age in America is one of rapid change in all industrial and engineering methods, such as has never been seen in the world before. Old established processes are being continually swept aside and replaced by new ones. These changes occur with kaleidoscopic speed and unexpectedness; and the man who has painfully armed himself with precedent and ancient lore finds himself hopelessly beaten before he can even make a start in the race. The American has always been characterized by his fertility of resource and power of adaptation. This has been his strength; his weakness has been his impatience to plunge into practice without a sufficiently broad and deep scientific training.

Fundamentals First.

I believe that we can trust to the American instinct of adaptability without much further attention. But that which is

most necessary, is to insist more and more on a solid foundation of scientific training to begin with. If we can secure for the American mining student a foundation training broad, deep and thorough in mathematics, physics and chemistry, he needs little else to make him invincible. The mining engineer must have a broader basal training than either the civil or the mechanical engineer, even though he specialize less. Mathematics, physics, and chemistry are necessary for all engineers; but for the civil engineer mathematics is fundamental, for the mechanical engineer physics is equally so, while for the mining engineer we must not only add physics, but also chemistry, with her closely related allies mineralogy and geology.

The training of the mining engineer cannot be too thorough in all these subjects. Each is an essential support to any superstructure that he may desire to build in the future.

Mathematics should include the differential and integral calculus, the theory of probabilities and the methods and criteria of approximations. A firm grasp of space-relations as developed in descriptive geometry is peculiarly important in following geological structure and vein-formations in the deeps of the earth. The mathematical work should be made familiar by numerous applications to concrete cases in which numerical results should be insisted upon. In this connection it is particularly important that the engineer should be made to realize that the most important part of his numerical result is the position of the decimal point, and only after that, the value of the first significant figure. Mathematical instructors too often neglect this, to the engineer, most vital matter. The sense of it should be made instinctive. It is much more important that mathematical instruction should be thorough as far as it goes than that it should feebly cover a large territory. The subject should be so thoroughly mastered that it comes to fit the hand like a well-worn tool.

No man is fit to teach mathematics to engineers who has not had some experience in its applications either to engineering, to physics or to astronomy. For only such a man knows just what to emphasize and what to omit, how to sympathize with, and how to inspire his students.

Men of prime ability in the mathematical faculty are absolutely the first essential in any engineering school. It is won-

derful how difficulties melt away like wax in the fire with a really able mathematical teacher. By such a teacher mathematics can be made as interesting as a romance to the average man; while it is often regarded as hopelessly difficult merely on account of the poor hands in which it is placed. To make new discoveries in the field of mathematics requires genius of a high order; but to master all the mathematics necessary for the intelligent practice of engineering requires no faculties beyond those of a logical mind, a certain power of imagination, and a reasonable degree of application. I have always found that the students who do well in mathematics do well in everything else that requires close thinking.

Instruction in physics and in mathematics should go on side by side; and the two courses should be so arranged that the mathematical principles may be at once applied to physical problems of a useful nature. The importance of actual numerical results should be always insisted upon. The student should be trained in the arts of observation and in inductive as well as deductive reasoning. He should acquire practice in the theory of approximations and should form the habit of judging or "weighing" his own results and of checking them by independent methods.

While the whole field of physics is important—the fundamental conceptions of analytic mechanics (acceleration, work, kinetic and potential energy) and their applications in hydraulics, thermodynamics, electricity and the like are vital, and cannot be too much emphasized.

Instruction in chemistry should be given parallel with mathematics and physics. It offers a fine training in inductive reasoning. Besides the usual courses in general and analytic chemistry, the modern methods of physical chemistry, as developed by such masters as Arrhenius, Ostwald, Nernst, and V'ant Hoff should be brought to the attention of the student, as soon as, by his collateral training, he is made able to understand them. It is not too much to say that the hope of the future, not only in biology, medicine and hygiene, but also in physical geology, the science of ore-deposits and the art of metallurgy, lies in this direction.

Such subjects as drawing, surveying, and mapping may also be carried on simultaneously with mathematics and physics,

each supplementing the other. Similarly, assaying and mineralogy give a new interest to chemical principles, to which they serve as useful applications. Geology, itself, important as is this noble subject, not only through its intrinsic interest, but also in its practical bearings, is really only an application of the principles of physics and chemistry to the study of the evolution of the earth. And it can be mastered only by him who has this training to build upon.

The same is true of every branch of engineering. Each is only the outgrowth of the application of the principles of the fundamental physical sciences to the needs of man. He who has this training has the master-key to the door of every industry.

The necessity for thoroughness in this fundamental work cannot be too much emphasized in American mining-schools. The impetuous preference of young Americans for what they deem "practical" is a serious hindrance to real achievement; and the only way to remove it is to convince them at the very start of the power and value of science. This can best be done by leading them, from the beginning, to apply science to some useful purpose. In short, they must be taught by experience the truth of Ostwald's saying: "The science of to-day is the practice of to-morrow."

There is much to be said in favor of the study of science for its own sake. We have all sympathized with the sentiment of the mathematical professor who "thanked God that he had at last discovered something that never could be put to any practical use." Still, it is a healthful instinct that leads most men to estimate the value of ideas by the use that can be made of them, and whether we approve it or not, the world will continue to do that, and we may as well adapt our plans to the fact.

To the man thus fundamentally trained nothing is impossible. He may still need to be made familiar with the general scope of each of the main branches of engineering, their relations to each other, the nature of the problems that each is called upon to solve, and the leading methods which, in each branch, have stood the test of time; and he should be made sufficiently familiar with the literature of the subject to know where to go for needed particulars; but any attempt to cram his memory

with the details of methods that may become obsolete, before he is called upon to use them, is a distinct and fatal mistake.

The Organizing Faculty.

The successful engineer is a creative artist in the use of materials and energy. In this class, he stands first, who with the smallest means produces the greatest results. Success will come most surely to him who clearly sees the nature of each concrete problem, and, from the widest outlook, chooses just the right methods, materials and forces of men and nature, to bring his undertaking to a successful issue.

Among engineers the creative or organizing faculty is a natural gift as rare as any other kind of genius. But fortunately it is a faculty most Americans have, at least in embryo, and it can be cultivated. All the work of a mining-school, whether in the basal sciences, or in the technical branches, may be utilized to develop it. Instead of possessors of encyclopedic erudition, there is needed a type of man that may mechanically remember less, but can do more. Such a man learns to analyze each problem that comes before him; when necessary, he runs down the literature bearing upon it; selects the good; rejects the bad; supplies by ready invention the missing link; decides what must be done;—and *does it*, cleanly, rapidly and with certainty, while the "encylopedio-maniac" is still digesting his erudition.

This kind of training, repeated again and again with every subject studied in the college course (at first in small and simple problems, later in larger and more complicated ones), does more to create the engineering faculty than anything else that can be devised. It is only by actually doing things that we learn how to do them. Action must follow reflection, and reflection must precede action for successful and useful life. Unless action follows reflection, life is "sicklied o'er with the pale cast of thought." Unless reflection precedes action we have all the ills that follow impetuosity, of which anarchy is the final and the bitter fruit. From this point of view the training of engineers has a moral effect on the whole body politic, since it tends to create a solid, well-balanced element in the community. Nothing develops a good man sooner than responsibility, which forces not only reflection, but action also. And the

sense of power that comes with the successful exercise of the creative faculties in the engineering arts is one of the purest and keenest pleasures of which our nature is capable.

The greatest service those in charge of the higher technical branches of the mining-school can render their students, is to show them how to apply their scientific knowledge to such practical problems as come before them. He who can do this for his students, and can give them a taste of that sense of power that comes from a mastery of the forces of nature, can trust them to go the rest of the road without a finger-post to point the way.

Personal Contact with Working-Conditions.

I have said that the mining engineer should learn to see clearly the problems that he must solve; that he must be familiar with the materials and the forces, not only of nature, but of human nature with which he must work. How shall he gain this knowledge? There is only one way: To become familiar with them by actual contact.

Should this experience come before, during or after the college course? It is most useful when it comes in all three ways. But coming only after the college course, it is altogether too late. Before that course, it can be usually gained only at the sacrifice of that general training, particularly in the languages and the humanities, that is so important to us all; and, moreover, before college-age the student is usually physically too immature to undertake such work. For these reasons it is usually best to let this experience begin with entrance into the mining-school. In each college year, as commonly arranged, from three to four months are given to vacations, which, occurring at regular periods in summer and winter, are admirably adapted to a progressive course of practical work in surveying, mining and metallurgy, in which the student can familiarize himself with practical conditions in different localities. For the reasons already given, this work should begin with the school course, and be carried on progressively, at regular intervals, with the theoretical work. It is thus practicable for the student to gain nearly a year of experience in a considerable range of methods. He is thus in a position to determine his own fitness for the work; to learn the branches for which he is

best adapted, and for which there is most demand; and to make acquaintances that will be useful to him afterwards. If he shows aptitude for the work, he is reasonably certain of finding the place for which he is suited; and if he does not, he can adjust himself to some other calling without further waste of time.

The importance of this training for the mining engineer is greater than in any other branch of engineering; for the conditions that he must meet are entirely different from those of any other calling. But it has been much more difficult to secure it under American than under European conditions. Besides, the lack of official connection between the mines and the mining-schools, there has been a strong prejudice against college-students on the part of practical men. This is partly due to experience with men trained exclusively in the old classical course, and almost helpless in practical affairs, because absolutely without knowledge or sympathy with nature. But it is also partly due to the self-assertion, flippancy and conceit of which young men just out of college are often guilty.

The "Mining-Laboratory."

Several solutions have been proposed to meet this difficulty. The first and most original is the so-called mining-laboratory, perfected through the pioneer work of Prof. R. H. Richards of the Massachusetts Institute of Technology. This has since become a prominent characteristic of American mining-schools generally, and is now being adopted in Europe. According to this plan, the leading operations of crushing, concentrating and working ores are executed by the students on a small working-scale in the laboratories of the school itself. In this way the schools have become partly independent of the mines, so far as the study of metallurgy and ore-dressing are concerned. In purely mining practice the problem is more difficult. I have for ten years, with some success, made an attempt in this direction, so far as rock-drilling and blasting are concerned. For this purpose, a mining-laboratory has been provided, in which the operations of sharpening, hardening and tempering drills, and the single- and double-hand drilling of blast-holes, as well as machine-drilling, are illustrated on a working-scale. Later, with the aid of an experienced miner, the operations of blast-

ing are conducted by the students in a neighboring quarry. In the new mining building, provided for the University of California by the generosity of Mrs. Hearst, it is proposed to extend this work, as far as practicable, to other branches. These devices have all proved very useful in familiarizing students with important current methods, under conditions where they may be controlled and studied in detail, even better than in the hurly-burly of practice. The mining-laboratory is one of the most important of the efforts of American schools to adjust themselves to their environment.

The Summer School of Practical Mining.

But, helpful as this method has proved to be, it still fails to bring the student face to face with the actual conditions of mining practice. The next important step was taken by Prof. Henry S. Munroe, of the Columbia School of Mines. For many years he has devoted much labor, with notable foresight, judgment, tact and discrimination, to the system now known as the Summer School of Practical Mining. To him, more than to any other one man, we owe this very useful adjunct, which has been adopted, with various modifications, by most American mining-schools. It is an outgrowth of the geological excursion, so long practiced in German mining-schools. But here it has been made to comprise the study, by a body of students, under the direction of their professors, of the leading operations of mining, dressing and working ores. One or more mining districts and several mines are visited, during a trip of a month or more. Surveys are made; sketches and notes are taken; and the student begins to acquire a first-hand knowledge of many conditions which he must afterwards meet.

An interesting modification of this method has just been attempted jointly, at the suggestion of Prof. John Hays Hammond, of the Sheffield School, and under the direction of Prof. H. S. Munroe, of Columbia, by the mining-schools of Columbia, Colorado, Harvard, the Massachusetts Institute of Technology, and Yale. It consists in hiring a mine for the summer, and putting the students at work under proper direction at the various operations of practical mining. In this way the mine for the time being is turned into a sort of school for the young men. This change certainly has many advantages. It comes

as near the European conditions as is possible in America. It enables the operations of the mine to be subordinated for the time being to the needs of instruction. This, for beginners, is certainly a great advantage. The method is, however, an expensive one; and several years of experience are necessary before it can be finally judged.

There is another modification of the Summer School idea, perhaps even more difficult of general application, with which I have had the most experience, and from which I hope much in the future. I began by visiting with my students various mining districts each year; but I found in this plan not only many advantages, but also many serious difficulties. One of the most fundamental of the latter was, that there is an important element which a man does not get by merely looking on. He often thinks he understands a thing that he sees another do; but such superficial knowledge is not to be trusted. It may suffice for amateurs and *dilletanti;* but real professional knowledge and power are not so obtained. It leads to that false sense of knowledge that makes practical men so disgusted with the man just out of college. It is the thorough, ingrained mastery which long familiarity with his work has given the practical man that makes him superior in any emergency to the mere "looker-on in Venice." Moreover, traveling with a large body of students tends to emphasize the difference between the students and the miners, and to make each party self-conscious, and, to a certain extent, antagonistic. When many students travel together, they carry with them the college-atmosphere, which is the very thing they need most to get away from, in their vacations. It is only when such a body of students is so diluted by dispersal among a large number of mines and miners who are *working* and *not playing* at mining, that they can be made to realize that they are not "the whole thing;" then, and then only, are they in a position to derive any real benefit from their experience.

These views were gradually forced upon me, as they doubtless have been forced on others, by a study of results. Moreover, as the number of students in the classes increased, I found it more and more difficult to secure accommodations for them in any but a few large mining-centers. This greatly limited the practicable scope and variety of the work.

But the cause that finally decided me to make a change was the lack of means, among some of the best students, to pay the expenses of such trips, in addition to those of the college course. Some of these men asked to be permitted to work for wages, instead of attending the summer school. This was done in certain cases; and I found at once such an improvement in the subsequent work of these students that I decided to alter my general plan accordingly.

The method, as thus far worked out, is to require that each student shall spend at least a month underground in the study of practical mining. As a matter of fact, most of the students thus spend from six to eight months during their college course, and many of them even more. Each must prepare a well-written account of his experiences, together with an essay, on a subject chosen by himself from among those that interested him most. These papers are read before the whole class and are discussed and criticized by all. Many of them have been extremely interesting and instructive.

The students are not required to work for wages, and are even discouraged from doing so, unless they are physically mature, and have some familiarity with the work. But, all are strongly urged to attempt this before they graduate. Most of them need very little encouragement; in fact, they take to it as naturally as ducks to water. There is a time in the development of a young man when hard work seems to be a physical necessity—an assertion of his manhood. It has even come to pass among us, that the young man who, from physical or other disability, does not do so, loses caste among his fellows.

There is of course a certain disadvantage in working for wages. A man has to do the same thing over and over again and is usually too tired to think much while doing it. But this objection is easily removed; for when, by a month or more of hard work, a man has established himself and paid his way, it is very easy for him to take further time at his own expense to get a general view of the work as a whole. Some men are of course physically unable to perform manual labor for wages. But, unless they are unusually well adapted for the profession in other ways, such bodily weakness is generally an indication that they had better adopt a less strenuous occupation. I have never found that the men have been lacking

in mental grasp from having to work; though naturally one cannot do hard labor and take voluminous notes on the same day.

On the other hand, there are certain great advantages in working for wages. It gives a man a just self-confidence, as nothing else can. He feels that no matter where he may be he can hold his own among men as a man. He learns the point of view of the working-miner, and how to win his confidence and respect. He gains an inside knowledge of the errors and successes of mine-administration. He comes to know the meaning of "a day's work," the tricks and subterfuges by which inefficient workmen seek to evade doing their duty, and the way to treat such cases without unnecessary friction. Such an experience is sure to prove invaluable, when, as he grows older, he is himself entrusted with the management of men. He will be more likely to know how to avoid unnecessary conflicts with his men from having himself "borne the heat and the burden of the day."

As a rule, men without previous experience are put first at loading and tramming cars, and later, at single- or double-hand drilling, or as helpers on a machine-drill; while in small mines they often have experience at timbering or at the pumps. Many of the men are really able to earn full wages as miners, before they get through. Often, when hard pressed for resources, they work a year, or even two years, underground, thus earning enough to pay their way through college. This seems rarely expedient, except in cases of necessity. But there are some cases in which an excess of animal spirits finds in such a rustication a natural outlet, and the man is really made over again by such an experience.

The men are advised not to go in groups, but usually in pairs, since, in case of illness or accident, a faithful "pardner" is a great source of comfort. They are also advised to scatter in a thin skirmish-line over the whole mining region west of the Rockies. Some go as far south as Mexico, others find their way to Cape Nome and the Klondike. Thus, like bees from the hive, they scatter over a wide area; each brings back honey of a slightly different flavor; and all benefit by this richer store.

Many difficulties were encountered, particularly at the begin-

ning, in carrying out this plan. Many still remain to be overcome before it can be perfected. It depends for success, not only on the goodwill of the miner and the mine-owner, but also upon the discretion and tact of the student. I have always found the miner, and nearly always the mine-owner, willing to help any young man of good physique and good nature who was not overcome with a sense of his own great knowledge and importance. But, when a very young man sets out, unasked, to show another man, old enough to be his father, how to run a mine, there is naturally trouble,—as there ought to be. For the first lesson a young man has to learn, is the necessity of adapting himself to his surroundings, and of fitting himself into his place in the greater mechanism; and, until he learns this, his lot is likely to prove rougher in the mining world than anywhere else.

There is much to justify the prejudice against a man who goes to college simply to escape doing his share of the world's work. Consequently, I have advised my students never to ask for work *because* they were college students, but simply because they were able and willing to earn what they were paid. In short, I have advised them to secure in their vacations the advantages of the "Wanderjahren" of the German apprentice. By scattering over a wide territory they are absorbed very naturally, and, as a rule, without much difficulty. Some of them have learned hard lessons not down in books, but it has done them good.

The men are all advised as to the principal precautions to be taken to preserve their health, the dangers they will have to meet and how to meet them. They are plainly told that unless they are ready to take the hard chances of the miners' life they had better choose some other occupation.

Among more than a thousand students who have participated in this work during the last fifteen years there have been but two serious accidents. Both of these were fatal. The victims were young men who had been working for nearly a year in the endeavor to earn enough money to pay their way through college. One was caught in a cave. The other, in firing a blast, had his candle blown out by the spitting fuse, and, in the darkness, was unable to reach a place of safety. But these very accidents have served to convince the mining public that

the California boys were enough in earnest to face the dangers of the miner's life.

This attempt at a solution of the problem is not presented as a general one; it is probably better adapted to western than to eastern mining conditions. It can only be applied when there exist a large number of mining camps within easy reach of the mining-school. Its best feature is, that it falls in with the American idea of free initiative. Moreover, it serves admirably to select the fit and reject the unfit without loss of time. It also automatically adjusts those questions of supply and demand that are so hard to settle.

In spite of its many imperfections, the system is beginning to bear fruit. The opposition to college men is growing gradually less. It is found that most of them are in earnest, and are willing and able to work, and that some of them have ability. Before the term of work is over a man is frequently told: "When you have finished college, I may have something for you to do." Many a man has dropped in this way into just the place for which he was adapted.

In short, if the college man can overcome the prejudice against him that often exists all too justly among men of affairs, by showing that he really is a man, modest, willing and capable; his education will have its chance to count in the end, as it does more easily at the beginning, under old world conditions. The only chance to make his start that the American mining student has, is to meet the practical man on his own ground. He can always do this if he has the courage to break the ice. It is better and easier for him to do this before he graduates than afterwards.

Physical and Moral Soundness and the Co-Operative Spirit.

Experience on these lines has emphasized the importance to the mining student of a sound and, if possible, a robust physique. By this I do not mean heavy muscles merely, but essential soundness of the vital organs, particularly those of digestion, circulation and breathing, and also the senses of sight and hearing. Important as these possessions are to all, to the mining engineer they are indispensable. An early physical examination by an experienced physician should reject all defective can-

didates as rigorously as is done in the army and navy. This should be followed by a thorough physical training, whose aim should be the production of a sound and healthy man. Some instruction in the fundamentals of hygiene, the precautions necessary in the use of food and water, the precautions to be taken in malarial regions and some knowledge of the "first aid to the injured," are very useful to men who must often serve as leaders of a forlorn hope in a strange land.

Even more important than physical soundness is moral soundness. It is absolutely necessary that mining engineers not only see the truth, but speak it. Scientific training, when thorough, always develops one important moral trait. It helps to elevate the love of truth into a religion. This is its greatest moral service to society.

In this connection we are all under indebtedness to the late Mr. A. M. Wellington for his able articles on "The Ideal Engineering School."[2]

Speaking of the young enginneer, he says: "He must be truthful and worthy of trust, must mean what he says and say what he means. If he cannot do this he must be silent." And again: "All men whose advancement depends on those above them must not only *be*, but also *seem*, faithful to those above them."

He calls attention to the fact that the lawyer, the physician and, to some extent also, the clergyman, depends for his success almost entirely upon his individual knowledge and intellectual abilities. Such a man may or may not be personally agreeable to those for whom he works; it is his knowledge and his technical skill that we wish to utilize in an emergency. These are his own possession, and he can utilize them unaided and without the co-operation of others.

But with the engineer this is not the case. His work cannot be done except through the friendly aid, not only of many engineering co-workers, but also through the help of capital and labor, the two most difficult elements in our civilization. From the inception of the original idea to its final completion, men and money, brains and brawn, nature and human nature, must work together without friction for a common purpose.

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[2] *Engineering News*, ——, 1893.

The young engineer must win the confidence of his superiors by a faithfulness and loyalty, free from subservience; he must secure the good-will and liking of his equals by frankness and openness of nature; he must command the respect of his subordinates by his evident mastery of his business, his sense of justice, his freedom from petty meanness, and his fearlessness in the discharge of duty. The man who cannot meet the requirements of any one of these three relations, no matter what his knowledge and technical skill, is sure to fail. And because they possess these qualities in a high degree, many men of very ordinary abilities often succeed as engineers, when men of superior genius lamentably fail.

When men must work together day and night, side by side, in intimate personal contact, where relations of subordination and command necessarily must exist, there must be no friction. Even a slight uncouthness of nature, or rudeness of manner, objectionable personal habits, or lack of tact, become simply unbearable at such close quarters.

All this is most emphatically true of the mining engineer. No men except soldiers, sailors, explorers and astronomers are subject to such a strain on their endurance.

As was also pointed out by Mr. Wellington, the necessity for the cultivation of the social graces and amenities of life, for habits of personal neatness, for self-control and uniform good nature under conditions of hardship and privation, have always been recognized as essential qualities in the army and the navy. That it is possible to cultivate these qualities, even in the most heterogeneous material, is evidenced by the success of our military and naval academies in producing them in the average American youth. The raw material they have to work on is not different from that which goes to our engineering schools. But the results they attain in this respect are so decidedly better that there is no comparison. In most engineering schools these important qualities are simply ignored, and no attempt is made to cultivate them.

Where, as in many of the so-called "Land Grant Colleges," a certain amount of military instruction and discipline is required, the means exist by which these qualities may be cultivated to some extent. In the University of California such is the case, and I have always found that the mining students

who, by attention to such matters, succeed as officers, invariably take high rank in their profession in executive positions. It is one of the few chances men in college have of learning the arts of controlling themselves and others. There is no agent so effective in forcing men to realize the means and advantages of co-operation as rigid military discipline. For the wars and struggles of our race since primeval times have polished and perfected this method till it has reached a high state of efficiency. But it is difficult for engineering schools to give the time and attention to it that is possible in a purely military school.

Another important means of reaching this end is to be found in all athletic sports in which, as in base-ball, boating and especially in foot-ball, team work plays an important part.

Organizing students into parties for surveying and other field and laboratory investigations, where each in turn acts as aid and as chief, is another effective means. In short, any agency that develops the instinct of co-operation, of team work, of the faculties of self-control, courtesy, fidelity and faithfulness, will prove effective. It will be more difficult to secure these qualities in America than it is abroad, because of the strong instincts of individualism and self-assertion that are such marked characteristics of American youth. Nevertheless, the uniform success of Annapolis and West Point in these matters testifies to its possibility. There is great room for improvement along these lines in all American engineering schools.

Sundry Minor Essentials.

There are also certain minor matters, too often neglected by both students and professors, which are peculiarly important to the young engineer in his first work after graduation, and all of which can easily be mastered in college; such as: neatness in drawing, mapping and lettering, certainty and rapidity in numerical work; in the measurement of angles and distances in surveying; and in sampling, assaying and the common methods of analysis. At first, accuracy is more important than speed. But the latter is, in practice only, less important, and should be insisted on from the beginning. A sound judgment on the degree of precision needed for the particular purpose in question is also indispensable. The student should be sure, on the

one hand, that his errors do not exceed this limit, and, on the other hand, that he does not waste time in needless refinement when approximations suffice. He should form the habit of always checking his measurements and calculations by at least two independent methods. The only way to insure this standard of accuracy and dispatch is to hold him to the hard standard that he will have to meet in practice, and to make him realize that for carelessness or blunders no explanations can be accepted. Rigid discipline on these lines should begin in the mathematical, physical and chemical departments, and should run right through the higher technical work with increasing severity. Tolerance of blunders is cruelty in the end.

General Training.

The mining engineer needs a certain fundamental training in economics, by reason of his position as an intermediary between capital and labor; his necessary dealings with merchants and contractors; and his handling of questions as to the valuation of mining-properties and the financing of mines. Besides the broad questions of money, interest, wages and other leading topics of economics, it is also important that he should be familiar with the laws of specifications and contracts, of ordinary business usage, the science of accounting, and the law of mines and water.

The broader the general culture with which a student comes to the mining-school, the better. The minimum entrance requirement should include some familiarity with general history, with the best of English literature, and the command of a simple, clear and forcible English style. A reading power of the leading modern languages is only less necessary than a mastery of one's mother-tongue.

As the training of the mining engineer must of necessity be chiefly scientific and technical, its natural tendency is to put him somewhat out of sympathy with the gentler side of human culture. It is important to counteract this tendency by keeping him in touch with the finer arts by which life is mellowed, enriched and ennobled.

Where, as is frequently the case in America, the mining-school is an integral part of a great University whose scope includes all the activities of our nature, this end is easily

and naturally reached by the association of mining students with other students who are devoting their lives to the arts, to philosophy and letters. The student is thus forced to become familiar with a wider outlook. Some touch with one of the finer arts, such as music, painting or sculpture, that will bring out the innate love of ideal beauty that exists in every man, is necessary to a well-balanced nature. Perhaps the most important of these influences is the cultivation of a taste for general literature, whose possession is a refreshment to the soul. The mining engineer who possesses it takes with him to the ends of the earth an inspiration that must make him an agency of moral and spiritual uplift wherever he may be.

Location of Mining-Schools.

Which is the better location for a mining-school:—a mining-center, or a commercial one? Successful mining-schools have been established in the older countries in both situations; Freiberg, Clausthal, Przibram and Leoben are examples of the former; and Paris, Berlin and London of the latter. Historically, the first to be established were in the mining-centers, which have the advantage of surrounding the student with a professional atmosphere, in which all the activities and ambitions of life gather about this one industry. When means of communication were poor, such a location was almost indispensable.

But such a location tends to make the training of the mining engineer provincial when it should be universal. Moreover, even in Europe, an end comes at last to a mining district, and the mining-school becomes stranded in a dying community. Some of the most famous of the European schools are already approaching this condition, which yearly becomes more desperate.

It is for this reason that the modern tendency is in the opposite direction. The most permanent of human institutions are the great commercial centers, made so by natural physiographic features, that facilitate intercourse, which is the life of trade. The capital that develops mines comes from these centers, and the profits from the mines return to them. The enterprise that undertakes great ventures has its source there,

and thence, confining itself to no national boundaries, reaches out to grasp the natural wealth of the world.

It is becoming more and more important that a mining-school should be located at the heart of things; for it needs to be not only permanent, but permanently strong; to maintain relations with capital not less than labor; and to have a cosmopolitan rather than a provincial outlook and sphere. It is as necessary as ever that the mining-school should be in close touch with many operating mines. But in modern times this is much more easily effected from commercial than from mining-centers. For these reasons, I believe that in the near future the positions of commanding importance will be held by mining-schools located near large commercial centers, particularly when these command not one, but many mining districts.

Over-Supply of Mining-Schools in America.

In a paper on "The Growth of American Mining-Schools and their Relation to the Mining Industry," read at the Engineering Congress at the World's Fair at Chicago in 1893,[3] I have already called attention to the relatively small proportion of miners among the wage-earners of the United States. According to the tenth census, the number was only 1.82 per cent. of the wage-earners, or 0.63 per cent. of the total population. The eleventh census showed a similar relation. The figures of the twelfth census show the total number of miners and quarrymen to have increased to 1.95 per cent. of the total wage-earners, or 0.75 per cent. of the population. It is impossible to determine from this report the exact number engaged in metallurgical work, but after a careful study of the data given, a liberal estimate for metallurgical laborers shows that the total cannot be for both industries much more than 2.5 per cent. of the wage-earners, or 0.95 per cent. of the population.

On the basis of the eleventh census (which contained no enumeration of mining or metallurgical engineers) I estimate that there could not have been at that time over 6,000 persons in the United States who practiced these professions. And that to keep up the supply would require about 200 new men per year. In the twelfth census the mining engineers were

[3] *Trans.*, xxiii., 444; also, *Transactions of the Society for the Promotion of Engineering Education*, Vol. I., 1893.

enumerated for the first time and the number given is only 2,908. Metallurgical engineers are not specified; but under the head of "Chemists, Assayers and Metallurgists" the number is 8,887. It is plain that a liberal outside estimate of mining engineers and metallurgists would be ten thousand; and to keep up the supply would take about 330 new men each year. By including assayers, mine-surveyors, and the various minor officials of mining and quarry companies, who might require some technical training, this number might possibly be doubled or even trebled. But when we remember that for many of these positions very little training is required, and that they are open to anyone who wishes to attempt the work, including many mining students who fail to graduate, it must be evident that there is a legitimate field for not much over 300 mining-school graduates each year. In 1893 I showed that there already existed in the United States a much larger number of mining-schools than was really needed; and the number is now much greater. The attendance at many of these schools has already increased enormously. At the University of California, for instance, the gain has been nearly 1,400 per cent. since 1887. There is no doubt that the demand for mining engineers in America can easily be supplied by the existing schools. It would be a distinct advantage if they could be restricted to a very much smaller number. Not more than six, or at most a dozen, favorably distributed according to the needs of the mining communities, could do all the work demanded of them much better than a larger number. Under American conditions no regulation but that of natural competition is possible. Much could be gained, however, if the existing schools would co-operate to fix a common standard for the degrees given. While no official relation with the mines is possible, the moral effect of such a step would be very great.

Degrees.

One of the reasons that so little attention has been paid in America to college degrees in the past is the great unevenness of the requirements for them in different parts of the country. Wherever a degree, or its equivalent, has come to mean something definite, as with our military and naval academies, it has received full recognition.

Still, there are indications of a general change in the public estimate of degrees. This has been most marked in regard to the degrees of Doctor of Philosophy and of Science. These have come to mean a capacity for original investigation in some branch of science or letters. It would be a distinct advantage to the mining-schools, and to the mining profession, if a similar definite meaning always went with that of the degree of mining engineer.

At present the practice of American mining-schools differs greatly in this matter. Some give the degree of mining engineer at the end of a four years' undergraduate course. One even gives it in three years; one has attempted a five years' course, but has unfortunately gone out of existence. Others give, for much the same amount of work, only the degree of Bachelor of Science at the end of the undergraduate course, and reserve the degree of Mining Engineer for advanced work.

I am convinced that no matter how excellent the course of a mining-school, it is a distinct mistake to give the degree of mining engineer on the same basis as that of the bachelor's degree. Some engineering schools, recognizing this difficulty, have attempted to institute as a mark of greater attainment the absurd degree of doctor of engineering.

The highest degree given by a mining-school should be that of Mining Engineer. This degree should be put on the same basis as that of Doctor of Philosophy, or of Science. It should be confined to those who have not only mastered the fundamental training, but have shown by actual accomplishment that they possess, in addition, the precious qualities of initiative and capacity as leaders in engineering, and also that maturity of mind and character which one naturally associates with the profession of the engineer. If this standard could be maintained, the degree of Mining Engineer from an American mining-school, in spite of its disconnection with government service, would soon stand higher than that of any other country in the world.

It must be evident that it is not possible to crowd a complete technical education into a four years' course, without neglecting the broad basal training that is necessary for advanced work. But, if some such plan as I have outlined were adopted

by the leading American mining-schools, a great advance would be made.

A large number of men could then take advantage of the undergraduate course which would then, in a new sense, and in a much higher form, take the place of the *Bergschule.* In this school all would receive the fundamental training necessary for the mining engineer, together with some knowledge of the various technical branches. After finishing this course of four years, and receiving the bachelor's degree, the best thing for all to do would be, as a rule, to plunge directly into the realities of the mining life. All could then step at once into the lower ranks of the profession. Most would undoubtedly be contented to remain there, filling a useful place in the general scheme, now occupied by men without either scientific or technical training; thus raising the standard of the entire industry.

But the chosen few who possess the creative faculty of the engineer should be encouraged to find their special bent and field as soon as possible, and then to throw their whole strength into a real mastery of the chosen specialty. A man is then in a position to specialize as much as may be necessary without becoming narrow. Three years of mature work along these special lines, in graduate work, either in college, or, under proper conditions, outside of it, should lead to the production of a piece of original work which would justly entitle him to the degree of Mining Engineer.

Such a policy would parallel, without imitating, the methods that have been so successful in encouraging advanced and independent workers in our Universities. It would create an American *Bergakademie* that would be superior to anything of the kind in Europe. And it would secure for America, by a process of natural selection, a body of mining engineers worthy of their natural heritage.